

Durham Research Online

Deposited in DRO:

29 September 2015

Version of attached file:

Accepted Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

McLean, Anthony and Bulkeley, Harriet and Crang, Mike (2016) 'Negotiating the urban smart grid : socio-technical experimentation in the city of Austin.', *Urban studies.*, 53 (15). pp. 3246-3263.

Further information on publisher's website:

<http://dx.doi.org/10.1177/0042098015612984>

Publisher's copyright statement:

McLean, Anthony and Bulkeley, Harriet and Crang, Mike (2016) 'Negotiating the urban smart grid : socio-technical experimentation in the city of Austin.', *Urban studies.*, 53 (15). pp. 3246-3263. Copyright © 2013 Urban Studies Journal Limited. Reprinted by permission of SAGE Publications.

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a [link](#) is made to the metadata record in DRO
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full DRO policy](#) for further details.

NEGOTIATING THE URBAN SMART GRID: SOCIO-TECHNICAL EXPERIMENTATION IN THE CITY OF AUSTIN

ANTHONY MCLEAN, DEPARTMENT OF URBAN STUDIES AND PLANNING, SHEFFIELD UNIVERSITY

PROF HARRIET BULKELEY, DEPARTMENT OF GEOGRAPHY, DURHAM UNIVERSITY

PROF MIKE CRANG, DEPARTMENT OF GEOGRAPHY, DURHAM UNIVERSITY

Keywords: urban; experiment; socio-technical; transition; smart grid; smart city; infrastructures; energy futures.

ABSTRACT

A growing body of literature has emerged that examines cities as key sites for socio-technical experimentation with a variety of initiatives and interventions to reduce carbon emissions, upgrade ageing infrastructure networks and stimulate economic development. Yet while there has been a wide survey of global initiatives and attempts to explain the wider processes driving such experimentation (Bulkeley and Castán Broto, 2013) there remains a lack of empirical case study analysis to bring the concepts into context. In this paper we use the concept of urban experimentation as a lens to discuss the political and social ramifications of one such intervention in a city's energy infrastructure network, with an examination of the Pecan Street smart grid project in Austin, Texas. The ability for cities to manage socio-technical transitions and their inflections by specific locales has been largely neglected in social science research, yet cities around the world are facing similar problems of ageing infrastructures, pressures of resource consumption and demanding shifts towards intermittent renewable technologies. We argue that cities are key arenas for the trialling, testing and development of smart products that can help transition towards a low-carbon economy, however the 'opening up' of cities as experimental nodes is contributing to a restructuring in socio-technical urban governance, creating new spaces for private investment while delegating responsibilities for carbon control down to urban citizens.

1) INTRODUCTION

Cities are huge consumers of resources and urban residents have become reliant on the often hidden infrastructure networks that aid their daily lives. Yet an ageing energy infrastructure, increasing consumer demand and the large-scale deployment of intermittent renewable generation technologies are leading to calls for a shift away from the current centralised, fossil fuel-based energy generation system towards a dynamic, decentralised and renewable-friendly network. Just as various crises and economic pressures in the 1970s led to changes in the management of large technical networks and the splintering of ownership (Graham and Marvin, 2001), in the 21st Century combined environmental, economic and social pressures are leading to a further transition in priorities and management. Over the past decade various movements have emerged calling for a transition towards 'smart cities' engaged with 'smart energy grids'. However a growing body of literature has emerged to critique the smart growth agenda, noting that demonstration projects are turning cities into digital marketplaces for large multinational firms, blurring the lines between public and private and concealing new forms of social and economic inequalities (Viitanen, 2013).

A number of studies have examined urban arenas as experimental sites well equipped to lead a transition towards a low carbon economy, providing spaces and tools for organisations to trial new models of infrastructural provision and management (Evans and Karvonen, 2011; Bulkeley and Castán Broto, 2013; Blok, 2013; Evans and Karvonen, 2014; Karvonen and van Heur, 2014). Urban environments can act as critical and effective arenas for addressing sustainability issues (Bulkeley et al., 2011) with vast resources of social and knowledge capital, information, and skills. Globally cities are seeking to position themselves as living laboratories for the innovation and testing of new green technologies. Such experiments are often seen as offering a "silver bullet for cities aiming to make the transition to a low-carbon economy, producing knowledge that will help them reduce their environmental impacts and resource consumption, generate new economic growth and develop reputations as leaders in sustainable development" (Evans and Karvonen, 2011: : 415). By producing knowledge 'in the real world' and 'for the real world', researchers can instigate rapid technical and economic transformation.

In this paper we explore the use of urban experimentation through the growth in smart energy grid projects. We argue that cities are key arenas for allowing the trialling, testing and development of smart products that can help moves in a transition towards a low-carbon economy. However we also argue that the 'opening up' of cities as experimental nodes is contributing to a restructuring in socio-technical urban governance, with the creation of new spaces for targeted private investment and the responsibilities of conservation efforts delegated down to an environmentally conscious citizenry. We aim to add to the literature with an in-depth case study of one smart energy grid project in the city of Austin, Texas, exploring how shifting governance arrangements in the city could lead to new forms of marketisation within the energy grid.

This paper forms part of the Durham University output of the Customer-Led Network Revolution, funded by the UK-based regulator Ofgem under the Low Carbon Networks Fund. Qualitative fieldwork was carried out over a four-week period in May 2012 involving semi-structured interviews with stakeholders of the Pecan Street Project. The paper begins with a look at the literature surrounding urban experiments before seeking to use the concepts as a lens to explain the global growth in so-called 'smart' energy grid initiatives. We then conduct an in-depth qualitative analysis of one such project, the Pecan Street Project in the city of Austin, exploring how certain experiments are opening up urban areas to outside interests, resulting in new organisational partnerships, new utility business models, and attempting to influence behavioural change amongst residents.

2) CITIES AS EXPERIMENTS

Cities are recognised as playing an increasingly significant role in responding to climate change (Bulkeley, 2005). While there are few locations that have developed a full and comprehensive set of policies and approaches to reduce carbon emissions, the number of initiatives and interventions being carried out in response to climate change is proliferating rapidly. Bulkeley and Castán Broto (2013) catalogue 627 urban 'climate change experiments' taking place in 100 global cities, involving eco developments, new technologies, specific policies, community-based initiatives, corporate buildings and infrastructure renewal programmes. Yet question marks remain over whether such experiments are restructuring governance relationships in urban areas, influencing citizens to behave in a more environmentally responsible manner or reinforcing existing neoliberal norms and processes. Certain demonstration projects have arguably been 'dropped into' urban areas from above rather than developed in tandem with citizen input (Hodson and Marvin, 2009a) while interventions may promote particular interests at the expense of others (Hodson and Marvin, 2007; Bulkeley and Castán Broto, 2013).

The growth of interventions in cities is arguably due to the potential for urban areas to act as 'motors' for sustainable development or 'hubs' for extreme forms of innovation in both transitional technologies and social behaviour (Ernstson et al., 2010; Broto and Bulkeley, 2013). Blok's conceptualisation of 'urban transition labs' describes locales where social change agents can "initiate or inflict urban sustainability transitions" (Blok, 2013: : 115). While many interventions are due to wider fears and obligations over climate change they can also be seen as something positive, desirable and potentially economically advantageous. Transitional experiments can be tailored to local settings instead of relying on city-in-a-box-type products sold by global firms. Differing visions on the future direction of a locale, urban developmental priorities and small-scale technological fixes can be brought together for consideration, integration and re-scaling within urban experiments.

In discussing climate change experiments Bulkeley and Castán Broto (2013) identify three types of urban experiment. The first is the policy experiment, concerned with policy and governance innovation. Climate change initiatives are taking place outside of existing channels of political authorities, with urban interventions part of a wider phenomenon in governance experimentation. In this context urban experiments can be seen as part of a

repositioning of the state with the creation of new state spaces. Some commentators see the process of 'eco-state restructuring' leading to a form of carbon control, creating a "distinctive political economy associated with climate mitigation in which discourses of climate change both open up, and necessitate an extension of, state intervention in the spheres of production and consumption" (While et al., 2010: : 82). Within governance and policy experiments it is useful to examine the differences in the "nature and type of experimentation in relation to variations in the political and economic dynamics of urbanisation, or in terms of who is leading and funding experimentation" (Bulkeley and Castán Broto, 2013: : 364).

A second type of intervention sees experimentation as occurring within specific niches or protected environments, sheltered from external political, social or economic pressures. This strand draws from the literature on the emergence of large technical systems and the development of a multi-level perspective (MLP) to understand the dynamics of such systems (Geels, 2002; Geels and Kemp, 2007). The MLP sees change as a result of interaction between three levels – relatively protected technological *niches* at the micro level within which experimentation and innovation can take place; socio-technical *regimes* at the meso level which constitute the mainstream, and highly institutionalised, way of currently realising societal functions; and the wider *landscape* providing a macro-level structuring context (Geels, 2004). Change in any socio-technical system can be achieved through interactions between different levels, for example outsider niches may break through when incumbent regime actors fail to re-orient their efforts in response to landscape pressures or in "major technological transformations in the way societal functions such as transportation, communication, housing, feeding are fulfilled" (Geels, 2002: : 1257). Niches are seen as vital to the process of wider socio-technical change, as during a transitional stage innovations created in niches have a window of opportunity to affect and challenge both the existing technological regime and the wider socio-technical landscape. Innovation is less a linear model of knowledge transfer but instead an iterative process of feedback between research institutions, governmental bodies, public authorities, users and private interests that occur in specific types of places. In the right circumstances these process can challenge regime dominance.

While these niche sites are largely seen in technological or market terms, they can also provide space for *social* experimentation allowing areas for "interactions between actors and for building social networks, enabling the articulation of expectations and visions and the alignment of heterogeneous resources including practical knowledge, tacit skills, tools, machines, money and people" (Bulkeley and Castán Broto, 2013: : 367). While social niches are often seen as evolving organically and operating outside existing institutional framework (such as through grass roots environmental movements) there is no reason why social niches cannot be fostered and nurtured by powerful actors operating in privileged spaces within existing governance frameworks. Many accounts oversimplify the processes and neglect existing power relations, conflicts of interest, latent capacities and discursive representations of change (Berkhout et al., 2004; Hodson and Marvin, 2010; Markard et al., 2012). Protected spaces may not be entirely immune from wider social processes, yet such niches are often treated as monolithic, driven by rational actors while the contestations, contexts and varying processes of differing locales are often neglected (Smith et al., 2005). Meanwhile the citizenry is often labelled as mere consumers of technology while their role

as “voters, members of interest or community groups, parents, friends, employees or employers” is often ignored (Whitmarsh, 2012: : 485).

A third type of experiment consists of urban ‘living laboratories’ where processes of innovation and learning are formalized. These experiments are a “specific type of niche that is often created by university-led partnerships to emphasize the importance of knowledge production” (Evans and Karvonen, 2011: : 415). They are centred on formalized knowledge production and represent a different form of experiment than policy experiments and niches of innovation. Experiments are not simply carried out inside hermetically-sealed laboratories, safeguarded from wider social and political process but operate in the ‘real world’ and serve to “create new forms of political space within the city, as public and private authority blur, and are primarily enacted through forms of technical intervention in infrastructure networks, drawing attention to the importance of such sites in urban climate politics” (Broto and Bulkeley, 2013: : 1935).

Such experimental interventions do not stand isolated in the urban arena. They should be “regarded as a means through which policies diffuse, as symptomatic of changing structures of political authority and opportunity, as a means for effecting socio-technical transformations, and of knowing and managing cities” (Bulkeley and Castán Broto, 2013: : 367). They can be strategic and purposive (Hodson and Marvin, 2007) and can advance particular interests at the expense of others, favouring firms and organisations willing to fund their own participation and can “provide grist in the urban mill, creating conflict, sparking controversy, offering the basis for contested new regimes of practice” (Bulkeley and Castán Broto, 2013: : 367)

While experimentation in these terms can involve a variety of socio-technical infrastructures, there has been a global emphasis on energy intervention in terms of climate change governance, suggesting experimentation is “frequently connected to issues of resource security and to the politics of carbon control” (Bulkeley and Castán Broto, 2013: : 372). In recent years such experimentation has focused on the ‘smartening’ of the energy grid, which is often framed in terms of a revolution in energy management, offering the possibility to reduce resource consumption, improve sustainability, and provide citizens with more control over their energy usage. Yet beyond the hype about the potential for smart energy grids ‘actually existing’ projects are usually found in specific urban experimental demonstration projects. In the next section we examine the growth of smart energy experiments and explore their potential to not only provide new conservation and generation technologies but also to alter social networks of the existing socio-technical system, a concept denoting the relatively stable configuration of institutions, technologies, rules and practices which is “both socially constructed and society shaping” (Hughes, 1987: 51).

3) SMART URBAN ENERGY

The ‘smart’ concept has attracted attention from a variety of academic fields and has become an umbrella term for a largely ecological holistic modernisation policy to create

environmentally sustainable economic growth. A key feature is the deployment of technology-based innovation in the planning, development and operation of cities in order to improve economic and political efficiency and to enable social, cultural and environmentally-friendly urban development (Hollands, 2008; Harrison and Donnelly, 2011; Neirrotti et al., 2014). Such technological developments promise to harness the advantages offered by continuous real-time flows of information, decentralised power generation and the ability to operate or automate appliances at a distance to make cities cleaner, more efficient and more environmentally friendly while simultaneously acting as a stimulus for economic growth. By making the “the invisible visible” (Harrison and Donnelly, 2011) and providing real-time information over resource flows and technological failures, planners and consumers can act rapidly to prevent potential bottlenecks and continuously optimise resource supply to avoid wastage. The smart city is thus “intended chiefly as an efficient, technologically advanced, green and socially inclusive city” (Vanolo, 2013: : 884). Smart technologies are being trialled in experimental zones across the world, while products are often presented as ‘city-in-a-box’ solutions that can be purchased off the shelf to solve the problems of upgrading and replacing decaying urban infrastructures.

While there is a growing literature on smart growth and the evolution of the wider smart city, it is the specific development of the smart energy grid that is of particular concern here. Ambitious greenhouse reduction targets and related infrastructure policies require a radical reconfiguration of the generation and consumption of energy (Rohracher and Späth, 2014). Yet despite the underlying political and economic changes that affected the energy grid since its creation (Graham and Marvin, 2001) the physical infrastructure itself has remained largely unchanged for more than a century. Energy is still generated in far-off power plants, transported through power lines that can cross continents and consumed in areas of demand far from initial generation. This structure has remained relatively stable with a clear separation of generation, transmission and consumption (Cardenas et al., 2014). Yet stringent climate targets for reducing greenhouse gas emissions, coupled with the deployment of new loads (i.e. electric vehicles), entail massive improvements in efficiency and a large scale introduction of intermittent renewable and low carbon energy generation (wind and solar). Coupled with the continuing need for material and ecological reproduction (Hodson and Marvin, 2009b) urban authorities are increasingly looking at their energy grids for deployment of decentralised ‘smart’ technologies (Coutard and Rutherford, 2011) which could offer increased local control. A shift to a smart grid in this context is expected to bring a number of benefits: lower utility operating costs, lower consumer costs through better societal resource utilization, nimble and flexible demand management offering increased reliability of the network and enhanced decision-making abilities for the consumer and/or the energy provider (Siano, 2014). By providing consumers with information about their energy use, encouraging consumption during off-peak times with real-time pricing signals and facilitating ‘load-balancing’ to enable the deployment of small-scale, decentralised generation, a smart grid could “improve both the physical and economic operation of the electricity system by making it more sustainable and robust, more efficient by reducing losses while at the same time offering economic advantages for all stakeholders” (Verbong et al., 2013: 117).

There are huge technical challenges associated with the implementation of a distributed generation system on an energy grid not designed for decentralised activity (Nepal and Jamasb, 2013) and to be successful smart technologies need to be developed, trialled and

tested before they can be deployed. Many smart grid projects are usually found in specific urban demonstration projects involving a mix of academic, municipal and private interests. In 2013 there were estimated to be more than 200 experimental smart grid interventions in operation around the world (Lewis, 2013) and in 2014 there were 459 in the EU alone, containing an average of nine partnering institutions. The places most likely to host smart grid projects are in “the vicinity of major organizations involved in research, innovation, or managing the national or regional transmission networks (major cities as London, Paris, Brussels, Barcelona, Roma or university centers as Bilbao, Grenoble, Arnhem, Karlsruhe, Copenhagen)” (Covrig et al., 2014).

Many projects involve the installation of smart meters to allow for the individual monitoring of energy consumption, representing an upgrade of one specific device transposed onto existing urban assemblages (for example a smart meter roll-out in the UK involves installing fifty million gas and electricity meters in twenty seven million homes by 2020). However certain projects require wider socio-technical shifts with experiments to influence citizen behaviour or to restructure grid management. Although it has been argued that previous ideological shifts and changes have led to splintered networks (Graham and Marvin, 2001) many of these market-orientated policies have so far focused on opening up new spaces for private investment and commercial involvement in the ownership and management of infrastructures. Consumers may have experienced changes in costs and investment levels may have varied considerably, but relatively little has changed in the physical nature of the networks themselves. New smart technologies have the potential to take the marketisation of the energy grid a stage further, opening up new possibilities for decentralised micro-generation, creating new spaces for markets to operate and transforming the urban citizen into a true *homo economicus* with responsibility over individual energy production and consumption. A number of experimental projects are trialling new contracts and pricing structures to persuade citizens to act as “prosumers” (implying producer and consumer) generating their own energy on-site and selling excess back to the wider grid. In London the Thames Valley Vision project includes the “installation of monitoring equipment in customer premises” and persuades customers to enter into “new contractual and commercial arrangements”. The MeRegio project in Germany aims to transform residents into “energy managers” with responsibility for their own energy use. Participants are offered control over their own consumption and costs while having the freedom to produce their own energy or to purchase it centrally. In Stockholm the Royal Seaport redevelopment project aims to turn residents into “active electricity consumers” generating and consuming energy on an individual basis. While many of these schemes offer clear environmental benefits, they raise wider concerns about new forms of social and economic inequality in an increasingly individualised network. Environmentally sustainable growth may not be distributed equally, creating new groups of politically and economically vulnerable citizens. The progressive discourse of environmentalism on display in some projects may in practice lead to the displacement or exclusion of the most economically vulnerable in a form of ecological gentrification (Dooling, 2009).

The smart ideal of an urban fabric hosting millions of decentralised power plants in constant communication with each other offers a radical shift in network management and raises questions over the possibilities of new governance arrangements. Who pays for the necessary back-office grid infrastructure to maintain such a marketplace? What happens to citizens excluded or bypassed and subject to the inequalities inherent in any market system?

Will those unable to install new generation and storage technologies be forced to enter into contracts that restrict their energy usage during peak consumption periods? The latter may well be rendered 'dumb' and unintelligent, non-conversant and incomprehensible to the network (Andrejevic, 2005). Lianos, discussing 'Automated Socio-Technical Environments', highlights the dangers of systems which "regulate, organize or monitor human behaviour by integrating it into a pre-arranged environment, built upon a conception of 'normality' or 'regularity' that all subjects are expected to reproduce" (Lianos, 2000: : 264). By creating a network that automates the thousands of daily energy transactions in a new consumer-to-consumer marketplace, smart grid technologies may facilitate exclusionary rather than inclusionary goals, creating inequalities not just within housing districts or between neighbourhoods, but in everyday consumption, lifestyle and leisure activities (Crang et al., 2007; Crang et al., 2006)

While concerns over resource consumption and carbon emissions are delegated down to individual citizens in a future smart grid, more powerful actors and privileged interests may benefit from the wider infrastructural shift. Hollands (2008) has argued that the smart infrastructure being deployed reflects a high-tech variant of Harvey's entrepreneurial city, that "beneath the emphases on human capital, social learning and the creation of smart communities" is a "more limited political agenda of 'high-tech urban entrepreneurialism'" (2008: : 314). Smart technologies may provide innovative ways to reduce carbon, decentralise energy generation, and provide security from external threats, but once they are released into the 'real world' they can become co-opted by corporate interests and subsumed under existing power relations. While many of the technologies offer clear benefits the 'smart' concept itself suggests a positive and uncritical stance towards urban development *in toto*, glossing over negative connotations and disguising contradictions inherent within innovative technological developments. While information and communication technologies (ICTs) are key economic drivers in urban areas there are both beneficial and detrimental social and spatial effects associated with their deployment (Graham, 2002). Studies of ecological modernisation policies have "already deftly demonstrated that such 'win-win' approaches to urban problems subsume environmental issues under neoliberalised concerns of 'efficiency, competitiveness, marketability, flexibility and development'" (Laidley, 2007: 261). Smart grids and their associated technologies are arguably a 'sustainability fix' (While et al., 2004) around which actors and discourses are beginning to establish positions in the urban arena, consolidating ideas around a consensual urban politics of strategic partnerships between elite and or powerful actors such as utilities, universities, housing providers and state institutions. Sustainability concerns have become secondary to economic competitiveness and "whilst there is talk of addressing social inequalities within a holistic approach to the economic, social and environmental domains, sustainability concerns have been internalised within neoliberal accumulation strategies" (While et al., 2010: : 82).

Many technologies central to the smart city and smart grid concept are developed, promoted and sold by some of the world's largest multi-national corporations. IBM promotes its Smarter Cities Challenge by shipping employees to cities around the world in three-week placement schemes to "work closely with city leaders and deliver recommendations on how to make the city smarter and more effective" (IBM, 2012). Some 100 cities have taken part at the time of writing. Microsoft offers urban managers a "broad portfolio of products and technologies, a global network of partners, and a long track-record

of successful education and social programs” to harness “the potential of all city residents to create healthier, greener, and more prosperous communities” (Microsoft, 2014) while Cisco claims to have ignited the entire smart city debate back in 2006 (Falconer and Mitchell, 2012). Cities are offered the opportunity to attract affluent workers and high-tech companies in a digital marketplace that has become a “a smokescreen for ushering in the business-dominated informational city” (Hollands, 2008: : 310). While many of the experimental projects on offer may lead to green and clean cities, this may be a by-product of the desire to attract highly mobile international capital and workers.

Despite the growth of literature surrounding smart cities and smart grids, there are few detailed case studies exploring how they work in practice, with little understanding of how the projects are developed, what their potential impacts may be, or how wider socio-technical networks are being affected. To rectify this we now examine one case study in detail, the Pecan Street smart grid project in Austin, Texas. Qualitative research was carried out in the city in May 2012. Semi-structured interviews were conducted with 16 stakeholders involved in the project, representing the city-owned Austin Energy and Austin Water, the city’s Chamber of Commerce, the University of Texas, city planners, private companies, the benchmark-providing Environmental Defense Fund and the Austin Technology Incubator. Participants were asked to discuss their role in the project, their aims and expected outcomes, their thoughts and concerns on the future direction of smart grids and general political, economic and cultural aspects of the city of Austin. Secondary research was also conducted, consisting of an analysis of documents outlining the evolution of the project and press materials discussing potential outcomes. With this case study we aim to provide not only a detailed account of the creation of a specific smart grid project, but also to examine the project’s use of an urban locale as an experimental node to develop new technologies, explore novel public private partnership working and to influence consumer behaviour.

4) AUSTIN: THE HIGH-TECH LIBERAL HEARTLAND OF TEXAS

There are four background factors that made Austin an attractive location to act as a test bed for a smart grid demonstration project. First, the state’s electricity grid is physically isolated from the rest of the United States, and with utilities operating almost exclusively within the borders of Texas they can avoid regional conflicts over who pays for the long-distance transmission lines for renewable energy – in Texas all customers share the cost equally (Behr, 2010). Second, despite being one of the most vocal states against regulations to combat carbon emissions, in 2010 renewable generation in Texas passed 10,000MW. This is largely due to renewable energy being seen as another economic resource to be extracted and put to productive use. Third, the City of Austin itself remains a liberal enclave in the Republican heart of Texas with a young, highly-educated workforce, a large high-tech sector and an energy discourse framed by ecological modernism, with a high quality of life to attract businesses and workers (Swearingen, 2010). Fourth, the city’s history with public-private partnerships – such as in the creation of research consortia Sematech and the Microelectronics and Computer Technology Corporation (MCC) in the 1980s – provides

experience and a latent capacity for state-directed economic investment with a self-image of cooperative technological innovation.

4.1) THE PECAN STREET PROJECT

The Pecan Street Project (PSP) is a public-private partnership with the “very modest goals of reinventing the energy system of the United States” (Planet Forward, 2012). The non-profit organisation is a smart grid project that is not only trying to roll out the new generation of technological assemblages (smart meters, electric vehicles and solar panels) but also examining future business models that could be used by a future utility in a decentralised marketplace. The project began in 2008 as a small start-up in an Austin coffee shop with an aim to digitize the grid to monitor and manage energy usage (Copelin, 2012) and has since expanded across Texas and into California and Colorado. It self-identifies as a bottom-up approach to the smart grid with new technologies being deployed in tandem with consumer input. As one interviewee explained, the technology needed to create a smart grid already exists but “the question is how do you get them into scale, how do you make it work, how do you reward people for using them?” (interview, Environmental Defense Fund representative, May 2012).

The project is focused on a volunteer group of 1,000 residents and 75 commercial businesses, largely concentrated in the city’s new Mueller district, a 711-acre site on the former Robert Mueller Municipal Airport which comprises a “self-selecting group of people living in a green community” (interview, Austin Energy executive, May 2012) with “environmentally conscious” volunteers and enthusiastic early adopters (interview, University of Texas professor, May 2012). Mueller is three miles from Austin’s central business district and in 2012 had the densest concentration of electric cars in the United States with 100 Chevrolet Volts. In 2013 The district’s population was around 23,000 people with a median household income of just under \$43,000. More than 70 per cent of workers were employed in white collar jobs (US Census Bureau, 2013).

The PSP is registered as a 501(c)3 venture – a non-profit organisation under US law covering scientific research which can attract tax deductible charitable donations. Although the University of Texas provided an initial \$50,000 to kick-start the project, major work did not begin until the US Department of Energy (DoE) provided a \$10.4 million grant in November 2009 (The DoE was awarded \$36.7 billion under the 2009 American Recovery and Reinvestment Act to develop renewable generation and promote energy conservation and efficiency schemes). This state support has been matched with \$14 million from external partner organisations, mainly private companies, to fund research for five years.

The PSP’s status as a non-profit allows it to act as an arms-length organisation outside of the control of any single public or private actor, although the founding partners play a key role in directing research. Six organisations have seats on the board –The University of Texas, the City of Austin, the city-owned Austin Energy, the Chamber of Commerce, the benchmark-providing Environmental Defense Fund and the Austin Technology Incubator (itself a business investment arm of the university). Below this board are a range of external companies that have provided funds and seconded staff to the project such as Freescale, LG,

Sony, Landis and Gyr, Intel and Best Buy. The partner organisations involved see the PSP as a way to “get things understood, experiments set up, information out into the public domain about what’s good, what’s bad and so forth” (interview, University of Texas professor, May 2012).

4.2) AN ARMS-LENGTH PETRI DISH

“We don’t care if Pecan Street succeeds or fails over in the Mueller area, it’s an experimental place” (interview, Austin Energy Executive, May 2012).

The city-owned utility Austin Energy allows researchers to use the grid as “sort of a platform” so they can “play around and test out new technologies” (interview, Austin Energy executive, May 2012) providing external partners with a safe test bed for products to be developed on an actually existing urban grid infrastructure. At one converted residential home in Mueller five different home energy management systems are being trialled along with three different setups for charging electric vehicles and numerous smart gadgets for home use. A press release calling for private partners to develop their own technologies explains:

“For smart grid to be truly transformative, the magic has to happen inside the house, and that’s where we’re going to focus our attention,” said Pecan Street Project executive director Brewster McCracken. ‘We know that utility-side improvements will play an integral role in solving major energy, economic and environmental challenges. But customer value can’t be an after-thought. Instead of imposing solutions on customers, smart grid must address these challenges by creating products and services that customers will value and voluntarily adopt’” (Pecan Street Inc, 2011).

One interviewee described how this more-than-technical approach meant the project was “a proving ground for the technologies and the ideas that we are going to be using in our advocacy for changing the rules, changing the market, providing new incentives, educating consumers” (interview, Environmental Defense Fund representative, May 2012). The project provides a sandbox for partner institutions to innovate without concerns of failure, with one interviewee describing the benefit of “putting all your mutations over in a safe petri dish” without having to worry about the universality requirement imposed on highly regulated utilities (interview, Austin Energy executive, May 2012). External partners can:

“...pay to be members of the technology board of advisors to help us suggest which experiments that need to be done, and they can help design the experiments and then they get to watch or even possibly participate in the experiments, and we don’t care, because there is nothing secret going on. I mean we all want to find out does this experiment work” (interview, Austin Energy executive, May 2012).

For partnering organisations the PSP provides ‘plausible deniability’ in the form of an arms-length ‘sandbox’ to allow the testing of technologies without the risk of a consumer or regulatory backlash. As one respondent described researchers from the variety of organisations involved:

“... most of these people can’t imagine doing things a little bit, and at the same time they also have this infinite demand to pilot everything, every utility, no matter how many times it has been done somewhere else, they want to pilot it too. So it’s very convenient to have a sandbox, a safe sandbox, a politically secure sandbox, in which they can play, and when the mood strikes the people from the utility can get more or less involved” (interview, Austin Energy executive, May 2012).

While the wider regulatory landscape allows for state-wide experimentation it is the Mueller district that provides the PSP with its physical urban site for experimentation. The new homes are generally the same age, it is largely isolated from wider Austin and there are a large proportion of early adopters and environmentally-conscious residents. For partners the benefits of this experimental safe zone is clear:

“For a politician you can imagine, ‘well give me a briefing I have got to do a press conference’. It’s a good mechanism for an NGO because they get huge leverage into organisations that they would otherwise have to fight their way into. It’s a real world filter on academic things, because academics tend to get all balled up in their research and reality is a mess to academics a lot of the time. So they can get a ‘ground trothing’ as we say here, a reference point in the real world through the organisation, they can get connections to the people that they want to have. So everybody has their own selfish theories, John Locke I think called it rational hedonism. Everybody has their own hedonistic objectives for wanting a seat and for wanting to go forward and it’s the right combination of that” (interview, Austin Energy executive, May 2012).

4.3) SMART ENERGY ROLL BACK

While researchers from both public (universities, city-owned utilities) and private (corporations, local businesses) sectors are carrying out experiments within the PSP it is the belief of many participants that the smart grid should be private-led rather than driven by the state. Distributed generation technologies and demand management systems for sale in an open market are preferred to a mandated state roll-out of smart technologies. Interviewees believed that any transition to a smart grid should be facilitated by willing customers buying products in a competitive market setting:

“We are trying to literally show that the public structure of the utility can enable these private innovations. The utility doesn’t want to get into the business of designing demand response technologies. That’s not what they do” (interview, Austin Energy executive, May 2012).

However this ‘rolling back’ of state involvement is problematic for the city-owned energy utility, as interviewees recognise that the deployment of decentralised generation networks and demand response technologies could reduce gross demand and therefore the utility’s revenue, on which the city relies for the provision of a range of otherwise non-energy related services:

“One of the things that concern the utilities is, if your programme really works you put us out of business” (interview, Austin Chamber of Commerce representative, May 2012).

The relationships between energy supply and consumption, grid management, and the provision of wider public services are context specific, but also reflect a wider pattern in smart grid innovation projects, with a common discourse on shifting grid management towards individual consumers, an increase in individualisation and a sharing of risk and investments between state and commercial entities. The techniques and apparatus through which grids are becoming smarter, although grounded in real concerns over resource consumption and environmental sustainability, are in many ways neoliberal in character, with an emphasis on individual choice-making as the engine for the transformation of energy provision. While the city of Austin provides the experimental space for technologies to be developed, and the private sector innovates and develops smart products, it is ultimately the individual homeowner responsible for reducing emissions and maintaining grid reliability by purchasing generation and management tools on the open market.

In the sun-belt zone of the United States small-scale solar power generation fits neatly alongside the peak demand period for air conditioning. In a future with individual citizens generating and consuming their own energy the city-owned Austin Energy, responsible for management of the large centralised network, could face an existential crisis. Researchers within the PSP are experimenting with a system in which the utility is transformed away from the current centralised model and into a socio-technical platform that facilitates peer-to-peer transactions between individual residents generating and consuming locally produced and locally circulating energy. At thousands of small distributed generation nodes the utility aims to embed metering apparatus to record transactions as well as energy flows in order to artificially construct and record the sale of discreet units of exchange as a means of disentangling an otherwise seamless state of electrical flow and potential. In so doing, the PSP is creating space for a new energy market to emerge and facilitating individual transactions between urban residents. In this scenario the utility will operate and maintain the underlying electrical infrastructure – transmission lines, a base generation capacity and an automated software management service – and in the new system will charge a subscription fee to those wanting to operate within the decentralised marketplace. Prosumers will be able to buy customisable smart technologies on the open market and generate and consume their own energy. One interviewee described this ‘brokerage’ system:

“I, as a utility operator, am going to be a sophisticated platform that provides energy one way when you need it, takes the energy the other way when you don’t need it, monitors the storage and the plug-in and brokers all this distributed onsite generation storage and consumption. I become the infrastructure, and I take a little fee for transactions for monitoring all this” (interview, former Austin Energy executive, May 2012).

The aim is to give individuals “choices and control as opposed to giving the utility or government control” (interview, Environmental Defense Fund representative, May 2012). However the way the market is being constructed loads those choices:

“I think ultimately what you do is give people options. You take this option; this is how much you pay. You don’t, then you are going to pay more. Because you are making the system cost more” (interview, Environmental Defense Fund representative, May 2012).

Thousands of prosumers will engage in constant micro-transactions with peers across the city and what was once a highly centralised, publically-managed grid network would

become a dispersed, variegated and dynamic marketplace – yet still reliant on a large technical network owned and operated by the city. On top of this platform third parties could develop their own software, hardware and services to sell to residents, while Austin Energy itself will provide a back-up guarantee of service to maintain a basic level of universality to the city.

4.4) THE NEW SMART MARKETPLACE

This scenario may be regarded as a further intensification of the process of infrastructural splintering that has taken place within many large infrastructure networks (Graham and Marvin 2001). By choosing to use a market-place as a decision making and resource allocation engine the system could introduce new forms of inequality into the urban fabric. For some socio-economic groups Austin Energy will become an energy provider of last resort with the development of highly individualised and specialised products and contracts to choose from. This is not necessarily a negative aspect of the future smart grid and will be welcomed by many. Residents with the time and resources will have opportunities and incentives to upgrade their own appliances to improve efficiency, install their own solar panels and storage technologies and then pay Austin Energy to manage their consumption and generation on their behalf. In effect, those able to do so will become players in the market, able to choose which flows to send or receive, which transactions to approve and on which terms to participate. In contrast, those unable to afford the capital investment required to become owners of the still expensive distributed generation technologies could be forced onto flat-rate pay-as-you-go contracts with constraining conditions attached to home appliance use. In such situations, those configured by rather than configuring the smart grid will be positioned within flows and transactions orchestrated to enhance the positions held by more powerful actors in the market place. For example they will be reliant on making their rooftops:

“...available to solar equipment owned by Austin Energy. They’d agree to reduced-cost appliance upgrades such as solar water heaters. They’d participate in Austin Energy’s demand response program, which might cycle off their air conditioners in fifteen-minute increments on the city’s hottest days. They’d agree to limit their peak use of non-essential appliances in favour of off-peak use. They would never be denied power when they need it. But they would agree that using energy at certain times – outside their service plan – would be ‘pay as you go,’ just like tossing more garbage than will fit in your city-issued trash can is ‘pay as you throw’” (Pecan Street Inc, 2010: : 16).

Although the cost of solar panels has dropped in recent years, the initial expense in installation could still be too expensive for many residents within Mueller, which has one of the largest affordable housing schemes in the country, involving 25 per cent of the district’s for-sale and for-rent residences. It is also not clear how residents in rental properties will overcome contractual issues with the installation of generation technologies. Creating a ‘pay as you go’ system for those unable to participate in Austin’s smart grid will mean the conditions of possibility for some participants’ energy use will be markedly narrower than is currently the case.. The potential was highlighted by one interviewee:

“...we might actually be on the threshold of a word we used to use in the early days, of ‘customerisation’. We might actually get to the place where this technology enables the utility to say ‘these are stay-at-home moms who keep their air conditioner running and run the dishwasher and have the TV running and a couple of other appliances, and we really ought to figure out a way to keep all of them from being on-peak at the same time’. Go to their house, put these controls in place, stop them from quadrupling their peak for a few minutes at a time. But in my house where my wife and I are both gone all day, don’t deploy the hardware. I would say that it’s probably going to be better for us to segment our customers before we try to deploy this crap to every single person” (interview, Austin Energy executive, May 2012).

While Austin Energy, a state institution, will be rolled back from service provision for urban residents able to be active in the market, it will be simultaneously increasing the scope of its interactions with residents unable to fully become prosumers by hard-controlling their appliance use and introducing dynamic and time-of-use pricing as ‘soft’ controls on overall energy demand .

5) CONCLUSION

In studying of the multitude of climate change experiments occurring in 100 cities around the world, Bulkeley and Castán Broto find support “for the argument that experimentation is taking place beyond the polity, as new forms of partnership, public and private authority emerge in the design of urban political spaces through which climate change can be pursued” (2013: : 372). While the study took a wide ranging look at the global perspective, context specific case studies are still largely missing from the literature. Detailed case studies of such experiments allow researchers to explore the diverse range of processes occurring in socio-technical networks at the urban scale. While many projects occurring on energy infrastructures promise to radically alter relationships between consumer and producer as well as blurring the distinctions between public and private, the literature is lacking in examinations of specific projects and the potential social, political or economic impacts such interventions may have. This paper offers such a study, and through the example of the Pecan Street Project we can draw attention to how smart grid experiments are reconfiguring socio-technical infrastructures in the urban context.

The Pecan Street Project opens up three arenas for experimentation. First, the physical opening up of the Mueller district and the wider energy grid infrastructure to outside researchers allows for innovative technological experimentation and the testing of products, contracts and business models in a ‘real world’ urban setting, on an actually existing grid network with actually existing energy customers. Companies such as Sony and Intel are able to test smart products that will be sold on an open market, while retailers such as Best Buy hope to gain recognition as a high-tech supplier with the expertise needed for complicated home installation packages. Academic partners are able to experiment with the energy grid and explore the treasure trove of data on energy consumption and behavioural patterns generated by the multitude of data collection nodes, while gaining a ‘ground trothing’ in the real world. While not exactly a protected, bounded space, the urban district of Mueller

provides a technological niche allowing for the iterative transfer of knowledge between partnering institutions.

Second, the Pecan Street Project (in line with many smart grid projects) acts as a new form of Harvey's urban entrepreneurialism, with the city experimenting in ways to attract investment through research-led public-private partnerships. Austin has a history of using public-private partnerships to develop its high-tech industry – with the creation of the Microelectronics and Computer Technology Corporation and Sematech in the 1980s – and the city's labelling as a "technopolis" (Smilor et al., 1989) reflects the success it has had. Several founding members of the Pecan Street Project were involved with the city's early research consortia and see the smart grid project as an evolution of previous partnerships to attract international finance and create a sustainable manufacturing industry (a key motivation for the participation of the Austin Chamber of Commerce). It has been argued elsewhere that new carbon-management approaches could become co-opted by economic development interests under a form of high-tech ecological modernisation (While et al., 2010) with sustainability concerns secondary to economic competitiveness. By contributing a relatively modest fee to fund research, a number of selected multinationals are able to design and participate in smart grid experiments in what would otherwise be unavailable spaces. The selection of certain partner organisations over others locks-out those without privileged access to decision makers, with the result that "if sustainability comes down to letting 1000 experimental flowers bloom, then it matters who gets to experiment, and how" (Evans, 2011: : 233)" (Bulkeley and Castán Broto, 2013). These kinds of partnerships blur distinctions between public and private authority while creating new forms of political space that provide certain interests with an advantageous position in influencing smart developments.

Third, the Pecan Street project is experimenting in the creation of new digital markets with attempts to turn citizens into 'prosumers' interacting with each other on a peer-to-peer basis. By 'rolling back' its own role as an energy provider, the city-owned Austin Energy hopes to become an energy *manager* that will facilitate transactions in a new smart marketplace. This new marketplace will offer spaces for external investment, with businesses developing plug and play devices (hardware and software) sold direct to consumers with little utility involvement, offering highly individualised demand response systems, decentralised renewable generation technologies and small-scale storage devices. Yet while the intent is for consumers to become responsible for their own generation and consumption, there will inevitably be those who cannot (or will not) participate. While the energy utility will scale back its interactions with some consumers (in some cases simply automating transactions in the new grid marketplace), with others it will need to increase its involvement and authority, controlling appliance use during periods of high demand and charging for energy use on a pay-as-you-go basis. The use of flexible markets to manage energy in this way represents a distinctive change in how urban power is provided and will represent a significant restructuring of social and political relationships.

While the Pecan Street Project is conducting experiments in a number of different ways, from the physical provision of the urban development, to a desire to develop a sustainable industry, and in attempts to influence behavioural change, the collection of interventions on display here represent just one possible direction for a future smart grid. By its very definition this is an experimental process. Cities around the world are facing similar

problems of resource conservation, environmental sustainability and economic competitiveness, and the 'smartening' of urban energy networks will be context-dependant and context-specific. However the Pecan Street Project provides vital insights into how certain urban experiments are proceeding and it demonstrates how interventions may contribute to new socio-technical regimes, new ideals for urban futures, and to shifting dynamics in urban governance arrangements.

REFERENCES

- Andrejevic M. (2005) Nothing Comes Between Me and My CPU: Smart Clothes and 'Ubiquitous' Computing. *Theory, Culture & Society* 22(3): 101-119.
- Behr P. (2010) Is Texas Writing the Book on Wind Power. *The New York Times*.
- Berkhout F, Smith A and Stirling A. (2004) Socio-technical regimes and transition contexts. In: Elzen B, Geels FW and Green K (eds) *System innovation and the transition to sustainability : theory, evidence and policy*. Cheltenham, UK; Northampton, MA, USA: Edward Elgar.
- Blok A. (2013) Urban Green Assemblages. *Science & Technology Studies* 26(1): 5-24.
- Broto VC and Bulkeley H. (2013) Maintaining Climate Change Experiments: Urban Political Ecology and the Everyday Reconfiguration of Urban Infrastructure. *International Journal of Urban and Regional Research* 37(6): 1934-1948.
- Bulkeley H. (2005) Reconfiguring environmental governance : towards a politics of scales and networks. *Political geography*. 24(8): 875-902.
- Bulkeley H and Castán Broto V. (2013) Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers* 38(3): 361-375.
- Bulkeley H, Castán Broto V, Hodson M, et al. (2011) *Cities and low carbon transitions*, Abingdon, Oxon; New York, NY: Routledge.
- Cardenas JA, Gemoets L, Ablanedo Rosas JH, et al. (2014) A literature survey on Smart Grid distribution: an analytical approach. *Journal of Cleaner Production* 65(0): 202-216.
- Copelin L. (2012) Pecan Street's aim: Create path for consumers into smart grid's future. *Austin American Statesman*.
- Coutard O and Rutherford J. (2011) The rise of post-networked cities in Europe? Recombining infrastructural, ecological and urban transformations in low carbon transitions. In: Bulkeley H, Castán Broto V, Hodson M, et al. (eds) *Cities and low carbon transitions*. Abingdon, Oxon; New York, NY: Routledge.
- Covrig CF, Ardelean M, Vasiljevska J, et al. (2014) Smart Grid Projects Outlook 2014. *Science and Policy Report by the Joint Research Centre* Luxembourg: European Commission.
- Crang M, Crosbie T and Graham S. (2006) Variable Geometries of Connection: Urban Digital Divides and the Uses of Information Technology. *Urban Studies* 43(13): 2551-2570.
- Crang M, Crosbie T and Graham S. (2007) Technology, timespace and the remediation of neighbourhood life. *Environment and planning A*. 39(10): 2405-2422.
- Dooling S. (2009) Ecological Gentrification: A Research Agenda Exploring Justice in the City. *International Journal of Urban and Regional Research* 33(3): 621-639.

- Ernstson H, van der Leeuw SE, Redman CL, et al. (2010) Urban Transitions: On Urban Resilience and Human-Dominated Ecosystems. *Ambio* 39(8): 531-545.
- Evans J and Karvonen A. (2011) Living laboratories for sustainability: exploring the politics and epistemology of urban transition. *Cities and low carbon transitions*: 126-141.
- Evans J and Karvonen A. (2014) 'Give Me a Laboratory and I Will Lower Your Carbon Footprint!' — Urban Laboratories and the Governance of Low-Carbon Futures. *International Journal of Urban and Regional Research* 38(2): 413-430.
- Evans JP. (2011) Resilience, ecology and adaptation in the experimental city. *Transactions of the Institute of British Geographers* 36(2): 223-237.
- Falconer G and Mitchell S. (2012) Smart City Framework: A Systematic Process for Enabling Smart+Connected Communities.
- Geels FW. (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy* 31(8-9): 1257-1274.
- Geels FW. (2004) From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy* 33(6-7): 897-920.
- Geels FW and Kemp R. (2007) Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society* 29(4): 441-455.
- Graham S. (2002) Bridging Urban Digital Divides? Urban Polarisation and Information and Communications Technologies (ICTs). *Urban Studies* 39(1): 33-56.
- Graham S and Marvin S. (2001) *Splintering urbanism : networked infrastructures, technological mobilities and the urban condition*, London: Routledge.
- Harrison C and Donnelly IA. (2011) A Theory of Smart Cities. *Proc. of the 55th A. Meet. ISSS*, 55.
- Hodson M and Marvin S. (2007) Cities mediating technological transitions: The adaptability of infrastructure and infrastructures of adaptability. *International handbook of urban policy*: 240-258.
- Hodson M and Marvin S. (2009a) Cities mediating technological transitions: understanding visions, intermediation and consequences. *Technology Analysis & Strategic Management* 21(4): 515-534.
- Hodson M and Marvin S. (2009b) 'Urban Ecological Security': A New Urban Paradigm? *International Journal of Urban and Regional Research* 33(1): 193-215.
- Hodson M and Marvin S. (2010) Can cities shape socio-technical transitions and how would we know if they were? *Research Policy* 39(4): 477-485.
- Hollands RG. (2008) Will the real smart city please stand up? *City* 12(3): 303-320.
- Hughes TP. (1987) The evolution of large technical systems. In: Bijker W, Hughes, T.P., Pinch, T. (Eds.) (ed) *The Social Construction of Technological Systems: New Direction in the Sociology and History of Technology*. MIT Press, Cambridge, MA, 51 - 82.
- IBM. (2012) *About the Smarter Cities Challenge* Available at: <http://smartercitieschallenge.org/about.html>.
- Karvonen A and van Heur B. (2014) Urban Laboratories: Experiments in Reworking Cities. *International Journal of Urban and Regional Research* 38(2): 379-392.
- Laidley J. (2007) The ecosystem approach and the global imperative on Toronto's Central Waterfront. *Cities* 24(4): 259-272.
- Lewis P. (2013) Smart Grid 2013 Global Impact Report. San Francisco.
- Lianos M. (2000) Dangerization and the End of Deviance: The Institutional Environment. *British Journal of Criminology* 40(2): 261-278.

- Markard J, Raven R and Truffer B. (2012) Sustainability transitions: An emerging field of research and its prospects. *Research Policy* 41(6): 955-967.
- Microsoft. (2014) *Microsoft CityNext*. Available at: <http://www.microsoft.com/government/ww/public-services/city-next/Pages/about.aspx>.
- Neirotti P, De Marco A, Cagliano AC, et al. (2014) Current trends in Smart City initiatives: Some stylised facts. *Cities* 38(0): 25-36.
- Nepal R and Jamsab T. (2013) Security of European electricity systems: Conceptualizing the assessment criteria and core indicators. *International Journal of Critical Infrastructure Protection* 6(3-4): 182-196.
- Pecan Street Inc. (2010) Working Group Recommendations.
- Pecan Street Inc. (2011) *Pecan Street Project Issues Call for Proposals Focused on Customers, Home Systems*. Available at: <http://www.pecanstreet.org/2011/02/pecan-street-project-issues-call-for-proposals-focused-on-customers-home-systems/>.
- Planet Forward. (2012) *A Few Smart Ideas to Clean Up and Re-energize Cities*. Available at: <http://planetforward.org/2012/02/06/a-few-smart-ideas-to-clean-up-and-re-energize-cities/?rel=viewprofile&uid=448>.
- Rohracher H and Späth P. (2014) The Interplay of Urban Energy Policy and Socio-technical Transitions: The Eco-cities of Graz and Freiburg in Retrospect. *Urban Studies* 51(7): 1415-1431.
- Siano P. (2014) Demand response and smart grids—A survey. *Renewable and Sustainable Energy Reviews* 30(0): 461-478.
- Smilor RW, Gibson DV and Kozmetsky G. (1989) Creating the technopolis: High-technology development in Austin, Texas. *Journal of Business Venturing* 4(1): 49-67.
- Smith A, Stirling A and Berkhout F. (2005) The governance of sustainable socio-technical transitions. *Research Policy* 34(10): 1491-1510.
- Swearingen WS. (2010) *Environmental city people, place, politics, and the meaning of modern Austin*, Austin: University of Texas Press.
- US Census Bureau. (2013) 2009-2013 5-Year American Community Survey, Selected Economic Characteristics.
- Vanolo A. (2013) Smartmentality: The Smart City as Disciplinary Strategy. *Urban Studies*.
- Verbong GPJ, Beemsterboer S and Sengers F. (2013) Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy* 52(0): 117-125.
- Viitanen JKR. (2013) Smart cities and green growth: outsourcing democratic and environmental resilience to the global technology sector. *Environ. Plann. A Environment and Planning A*.
- While A, Jonas AEG and Gibbs D. (2004) The environment and the entrepreneurial city: searching for the urban 'sustainability;fix' in Manchester and Leeds. *International Journal of Urban and Regional Research* 28(3): 549-569.
- While A, Jonas AEG and Gibbs D. (2010) From sustainable development to carbon control: eco-state restructuring and the politics of urban and regional development. *Transactions of the Institute of British Geographers* 35(1): 76-93.
- Whitmarsh L. (2012) How useful is the Multi-Level Perspective for transport and sustainability research? *Journal of Transport Geography* 24(0): 483-487.